FERMILAB-Pub-96/068-A

Comment on a Paper by Fang, Huang, and Wu

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Before decoupling in the early universe, the tightly coupled photon/electron gas underwent acoustic oscillations. These oscillations should be visible today in the spectrum of anisotropies. Recently Fang, Huang, and Wu (1996) claimed that when random processes are accounted for, the phases of these oscillations are no longer coherent. In fact, they claim that the well-defined peaks will be completely smoothed out. We show here that their claim is incorrect. The standard Boltzmann treatment determining the anisotropies is sufficient; random processes do not change the standard result.

Our criticism has two parts, both dealing with their equation 26. The first point is that – at least to a first approximation – the power spectrum today is caused by the monopole at decoupling. If Θ_0 were zero at decoupling there would [again to first approximation] be no anisotropy today. Fang et al. derive an expression for the phase shift for each of the $l-$ modes (their eqn. 25), but the only one of these phase shifts that is relevant is the $l = 0$ mode. All the higher modes [with the minor exception of the $l = 1$ mode]

have negligible amplitudes in the tightly coupled regime. The final anisotropy spectrum today depends then only on this one phase shift $\delta\phi_0(\eta_*)$. So we disagree with eqn 26 which assumes that the shift in a given multipole of the power spectrum depends on the phase shift of that multipole at decoupling. To make this slightly more quantitative, let us write the standard expression for the power spectrum:

$$C_l = \frac{2}{\pi} \int dk k^2 j_l^2(k\eta_0) \left[\Theta_0(k, \eta_*) + \psi(k, \eta_*)\right]^2$$

The spherical Bessel functions take care of the free-streaming from the last scattering surface to us today. This equation neglects the small contributions from the dipole and from the integrated Sachs-Wolfe effect, but this should be irrelevant for the present purposes. If we write $\Theta_0(\eta_*) + \psi(\eta_*) = A\cos\left(\phi_0(\eta_*) + \delta\phi_0(\eta_*)\right)$, then the change in the power spectrum due to a change in the phases should be roughly

$$\frac{\Delta C_l}{C_l} \propto \delta\phi_0^2(k = l/\eta_0, \eta_*)$$

This equation should replace equation 26 in their paper.

Our second point is that the shift $\delta\phi_0$ is zero! The authors point this out earlier in their paper. Physically it makes sense that $\delta\phi_0(\eta_*) = 0$, for energy must be conserved in interactions. Since $\delta\phi_0$ is zero due to random fluctuations, the change in the power spectrum is also zero. There may be small residual corrections due to fluctuations in the quadrupole at recombination (because the photons and electrons are tightly coupled, no momentum is lost from the dipole so $l = 1$ fluctuations are also strongly suppressed) but these should be very small. We conclude that phase randomization does not disrupt the structure of the "Doppler peaks."

We thank Lam Hui for a helpful comment. This work was supported in part by the DOE and NASA (at Fermilab through grant NAG 5-2788).

References

Li-Zhi Fang , Zheng Huang , & Xian-Ping Wu 1996, astro-ph 9601087